



# Returning to the Moon: NASA's Artemis Missions

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Engineering Project Manager  
NASA Ames Research Center



# PERSONAL INFORMATION



- Project Manager for Orion (Multi-Purpose Crew Vehicle) operations at NASA Ames Research Center since 2018
  - Orion is one of the elements of NASA's Artemis program with objective to land the first woman and next man on Moon by 2024
- Project Manager for Science mission proposals
- Prior to current role, I spent 11 years in Entry Systems division designing, developing and testing heatshield materials and systems. I had the opportunity to work on many different projects at NASA.
  - Mission concept studies to send probes to Ice giants
  - Thermal analysis of Entry vehicles
  - Asteroid entry on Earth and their break-up



Returning to Earth at  
25,000 MPH





# ARTEMIS

Twin sister of Apollo and goddess of the Moon in Greek mythology, Artemis is the torch-bringer personifying our path to the Moon. During the next era of human exploration, we will discover life-saving, Earth-changing science and technology along the way.

NASA's goal is to land the first woman and first person of color on the Moon and return them safely to Earth. When the Artemis astronauts land on the lunar surface, they will step into the future, bringing all of humanity with them.



# VALUABLE LUNAR SCIENCE



Study of Planetary  
Processes



Understanding  
Volatile Cycles



Impact History of  
Earth-Moon System



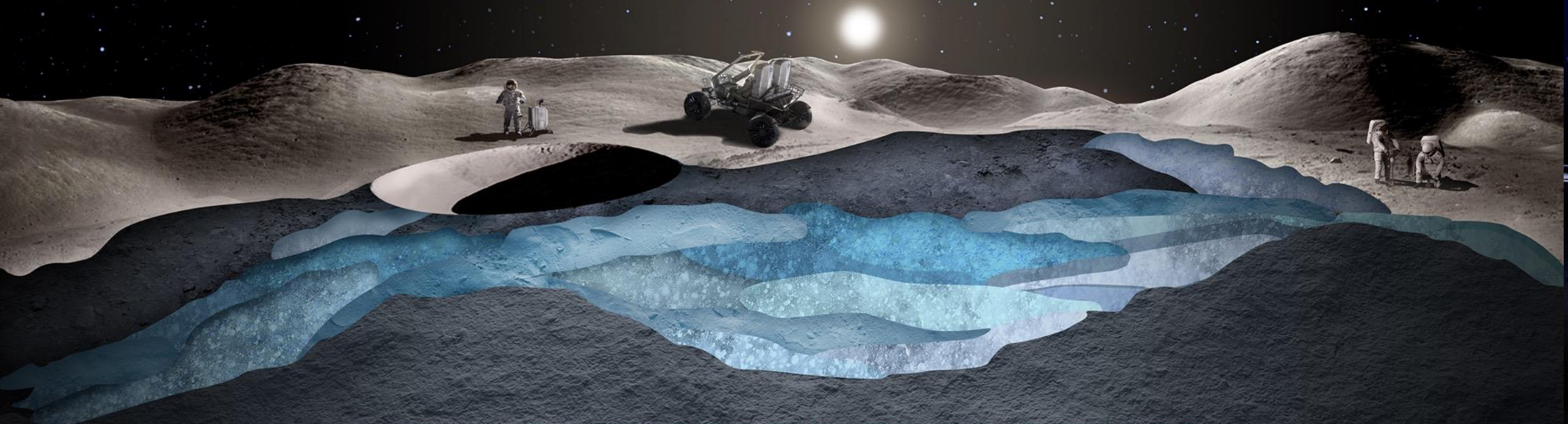
Record of the  
Ancient Sun



Fundamental  
Lunar Science



Platform to Study  
the Universe



## LUNAR SURFACE SCIENCE OBJECTIVES

Why Artemis?

# DISCOVER

With Artemis, we're building on more than 50 years of exploration experience to reignite America's passion for discovery



## VIPER

Volatiles Investigating Polar Exploration Rover



Locate concentrations of water ice that could eventually be harvested to sustain human exploration on the Moon, Mars — and beyond. VIPER represents the first resource mapping mission on another celestial body.



# DISCOVER

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## ISRU

In-situ resource utilization

- Propellant material mining
- Material synthesis for 3-D Printing on the Moon

For sustainability on the Moon and future human missions to Mars.



# OPPORTUNITY

Artemis missions **enable a growing lunar economy** by fueling new industries, supporting job growth, and furthering the demand for a skilled workforce.





# INSPIRATION

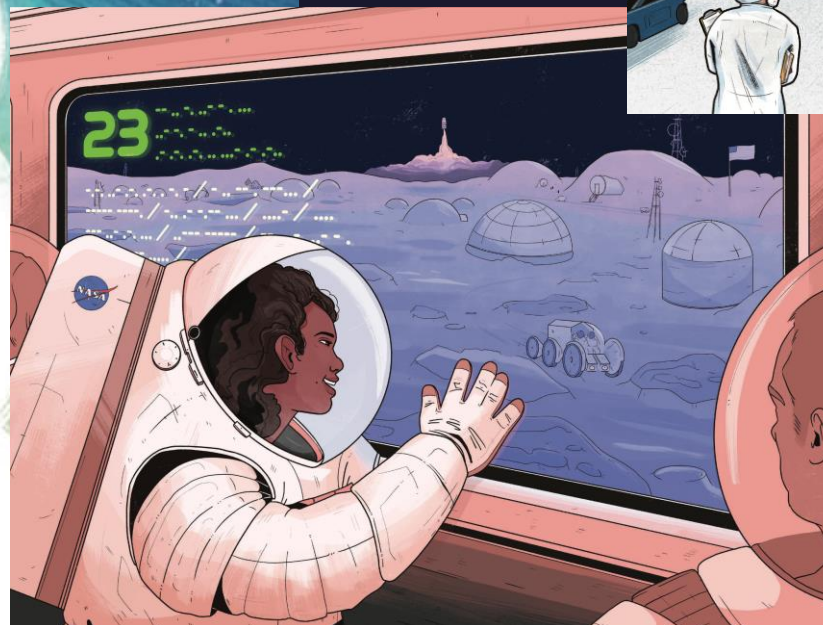
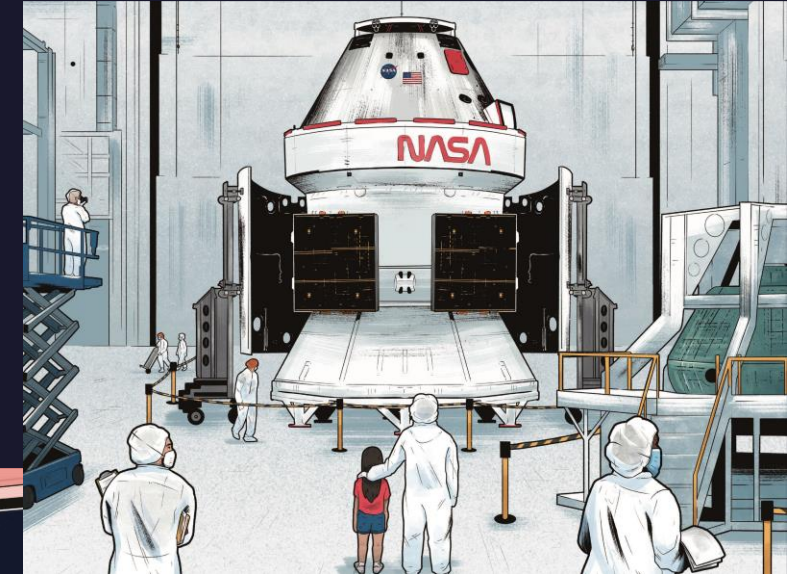
With Artemis missions, NASA will land an inspirational crew on the Moon, using innovative technologies to expand human exploration.



ILLUSTRATED BY SHANE TOLENTINO

# YOU ARE GOING

A STORY ABOUT ARTEMIS



# Mission Needs Drive Design



## LOW EARTH RETURN

**3 HOURS**

**3,000°F**

**17,500 MPH**

**250 MILES**



## LUNAR RETURN

**3 DAYS**

**5,200°F**

**24,700 MPH**

**240,000 MILES**



## MARS RETURN

**9 MONTHS**

**6,200°F**

**26,800 MPH**

**39,000,000 MILES**



*\*Numbers are averages*



# Artemis: a Foundation for Deep Space Exploration



Space Launch System



Orion spacecraft



Human Landing System



Surface Operations



Gateway



Exploration Ground Systems



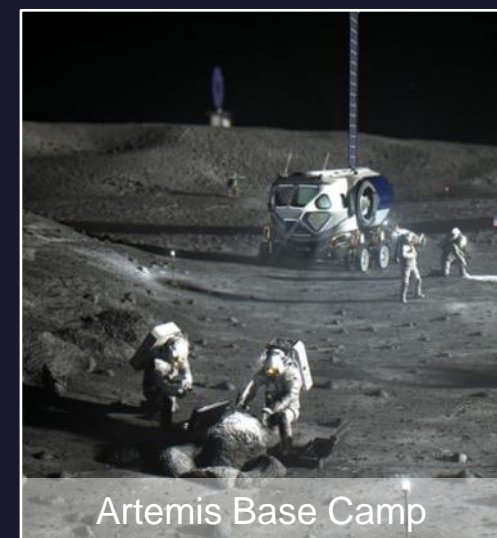
Space Communications  
& Navigation



Surface Mobility



Space Suits



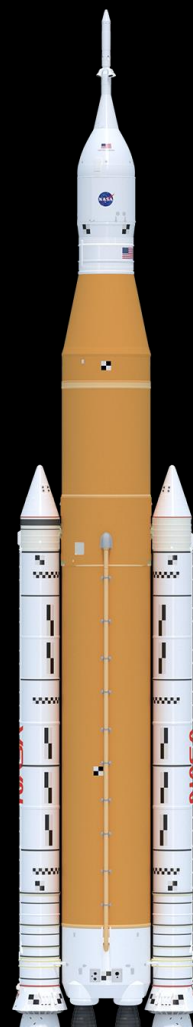
Artemis Base Camp



STATUE OF LIBERTY  
305 ft.



SPACE SHUTTLE  
184 ft.



SLS / ORION Block I  
322 ft.



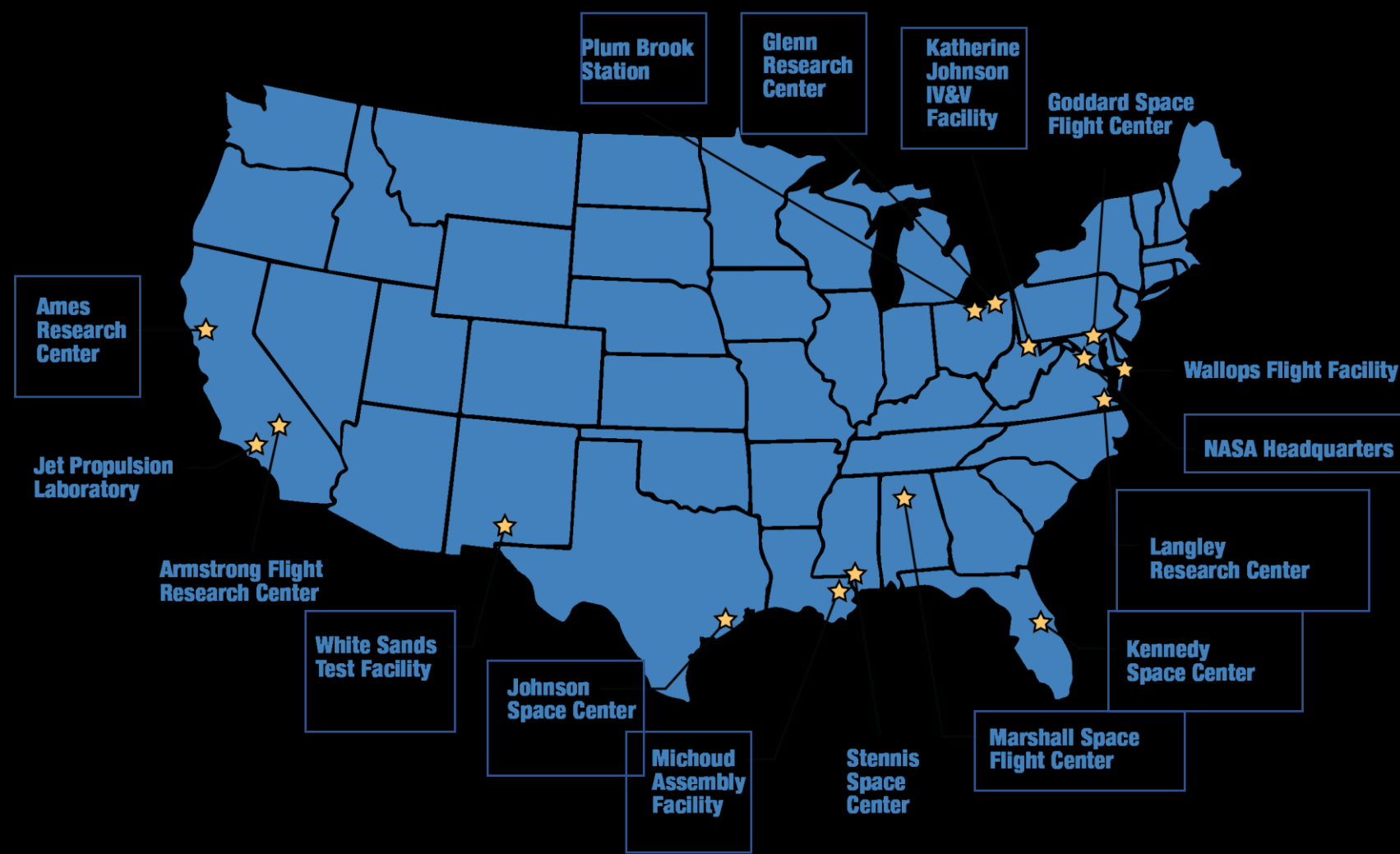
SLS / ORION Block II  
364 ft.



SATURN 5  
363 ft.



# Key Artemis Contributions by NASA Centers





# SLS





# EGS







ORION



# Orion Quick Facts

Performance		Height	
Number of crew	4	Crew module + service module	26 ft.
Mission Duration	up to 21 days	Orion stack (launch abort system + crew module + service module)	67 ft.
Trans-Lunar Insertion Mass		SLS Block 1 Configuration (Orion + SLS stack)	322 ft.
Artemis I	53,000 lbs.	Post-Trans Lunar Insertion Mass	
Artemis II	58,000 lbs.	Artemis I	51,500 lbs.
Gross Liftoff Weight		Artemis II	57,000 lbs.
Artemis I	72,000 lbs.	Usable Propellant	19,000 lbs.
Artemis II	78,000 lbs.	Total Change in Velocity ( $\Delta V$ ) with Fully Loaded Propellant Tank	
		Artemis I	53,000 lbs.
		Artemis II	58,000 lbs.

# HOW WE GET THERE!

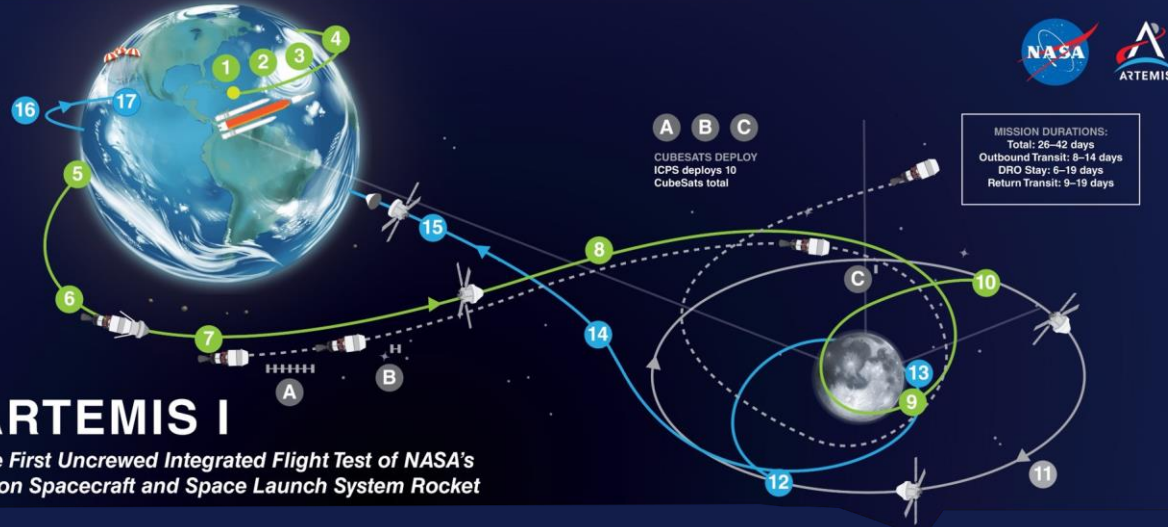




# HOW WE GET THERE!



# HOW WE GET THERE!



## ARTEMIS I

*The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket*



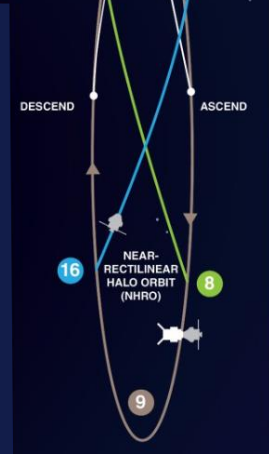
## ARTEMIS II

*First Crewed Test Flight to the Moon Since Apollo*



## ARTEMIS III

*Landing on the Moon*







# ARTEMIS I MOON ROCKET

## ORION SPACECRAFT

An uncrewed Orion spacecraft will venture thousands of miles beyond the Moon, paving the way for future flights with astronauts.

## ORION STAGE ADAPTER

The adapter carries small satellites to deep space where they conduct world-class science for pennies on the dollar.

## INTERIM CRYOGENIC PROPULSION STAGE (ICPS)

One RL10 engine provides 24,750 pounds of thrust to send Orion to the Moon.

## LAUNCH VEHICLE STAGE ADAPTER

The adapter connects the 27.5-foot diameter core stage to the 16.5-foot diameter ICPS and partially encloses the ICPS in-space stage.

## CORE STAGE

The 212-foot tall core stage holds 733,000 gallons of propellant to power four RS-25 engines for eight minutes, sending the rocket soaring to space at 17,000 miles per hour.

## SOLID ROCKET BOOSTERS

Each 17-story-tall booster generates 3.6 million pounds of thrust, providing 75 percent of total thrust during the SLS rocket's first two minutes of flight.

## FOUR RS-25 ENGINES

As the most efficient engines ever built, the engines provide a total of two million pounds of thrust for launch and ascent to space.

NASA'S SPACE LAUNCH SYSTEM (SLS) is the only rocket built to send more than 59,525 pounds to deep space.

Once in space, need **24,750 pounds** of thrust to send Orion to the Moon!

Total of **5.6 Million pounds** of thrust to lift 59,525 pounds from the Earth's surface, escape gravity.

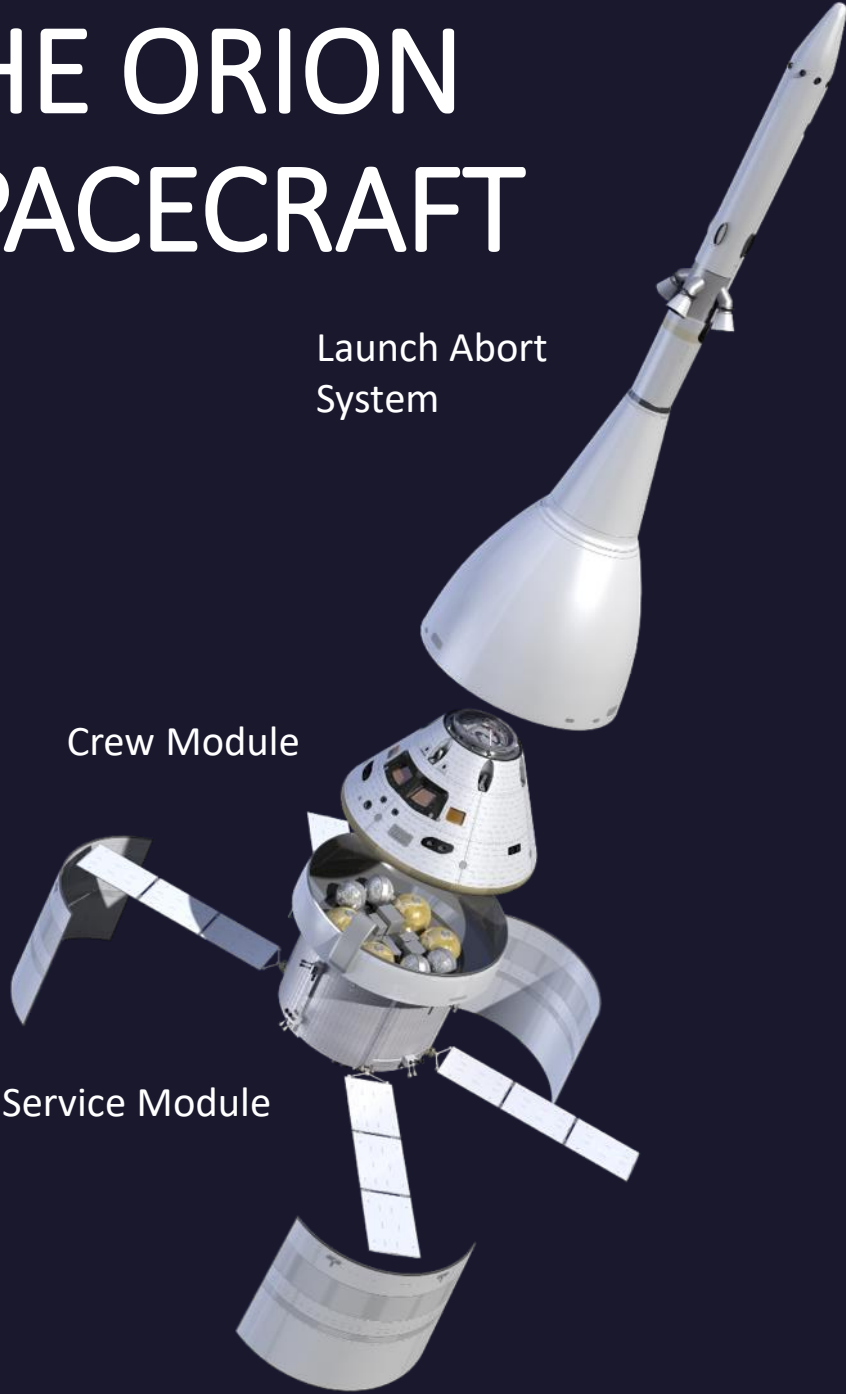
# THE ORION SPACECRAFT



Launch Abort System

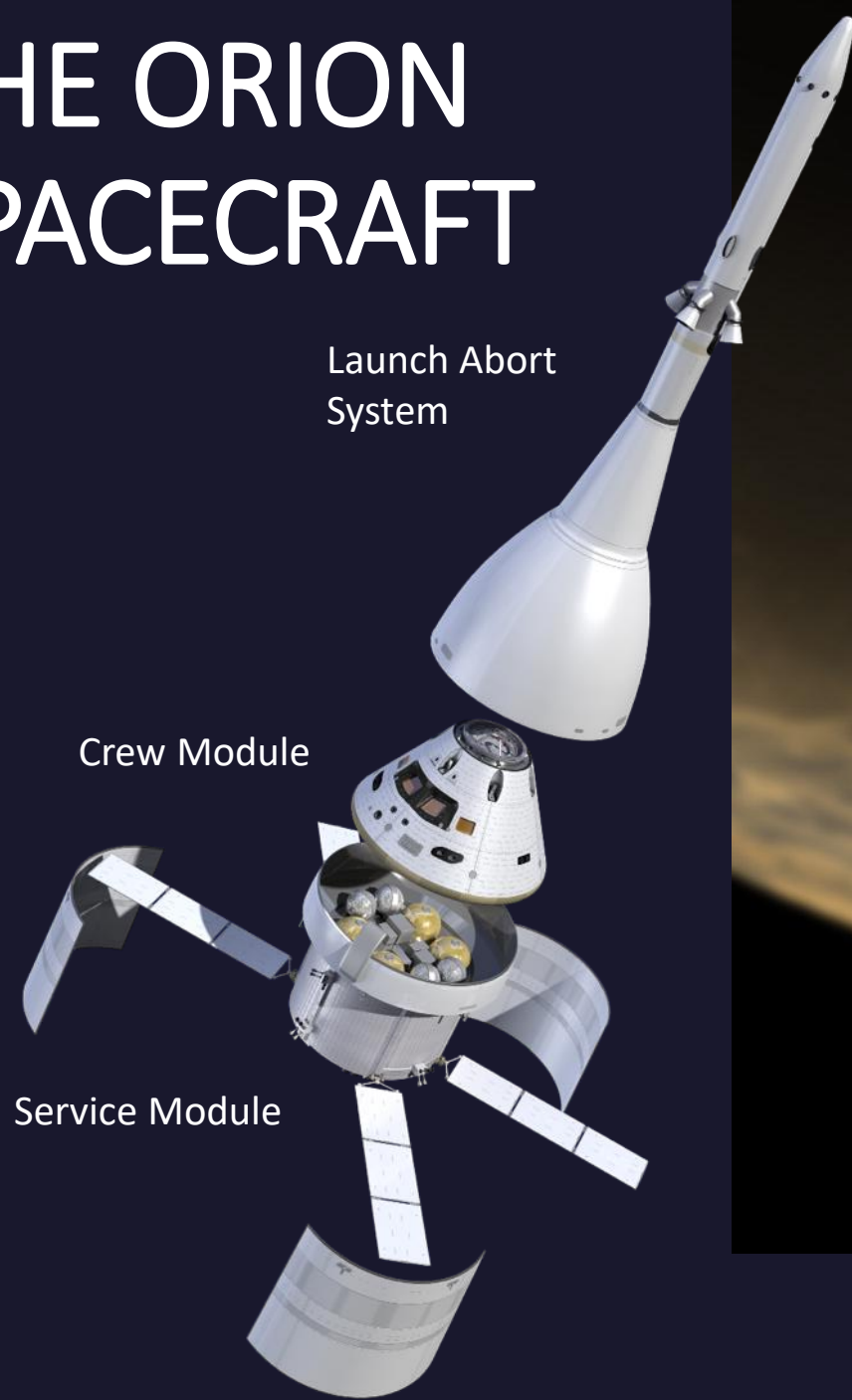
Crew Module

Service Module



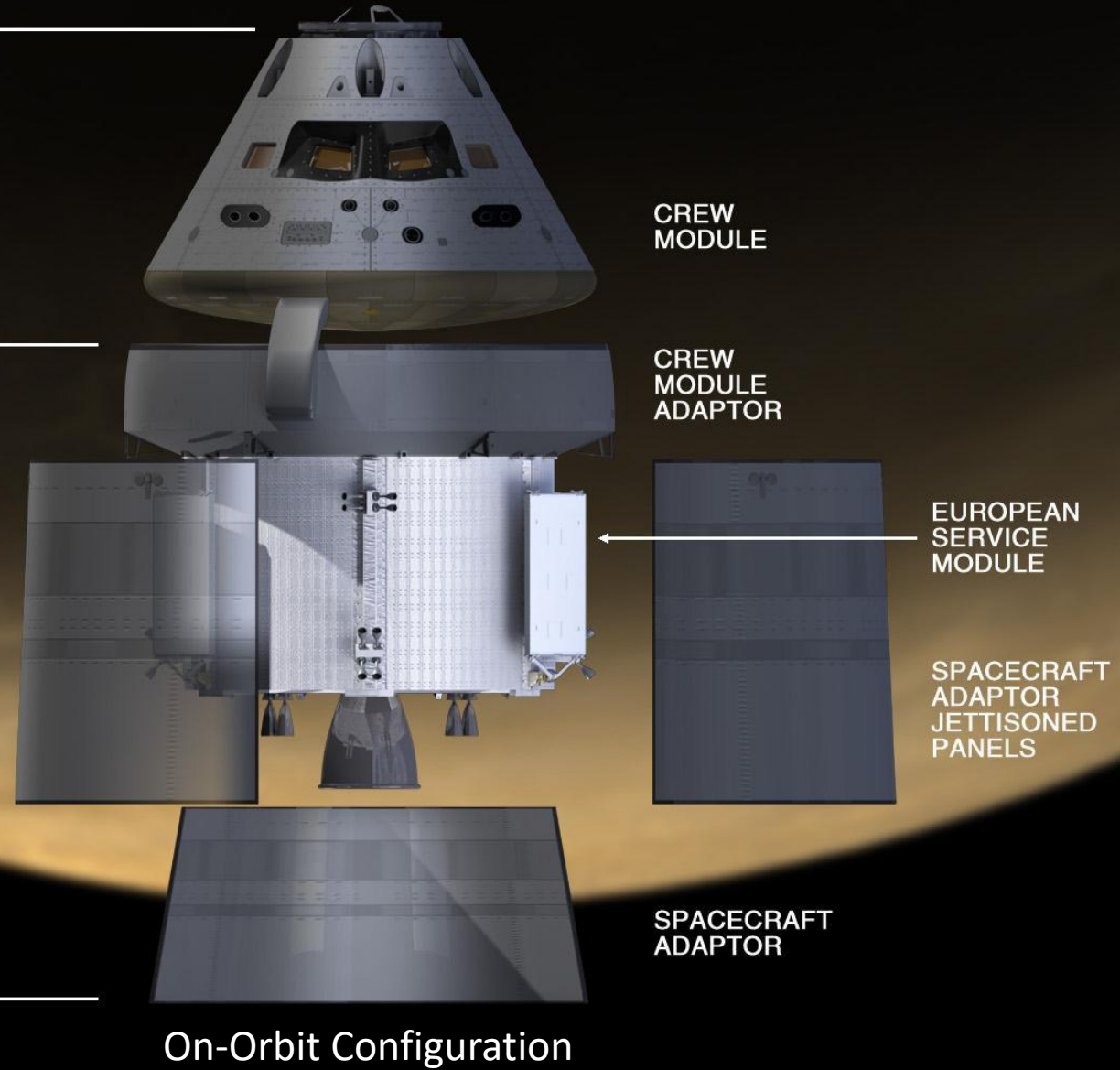


# THE ORION SPACECRAFT

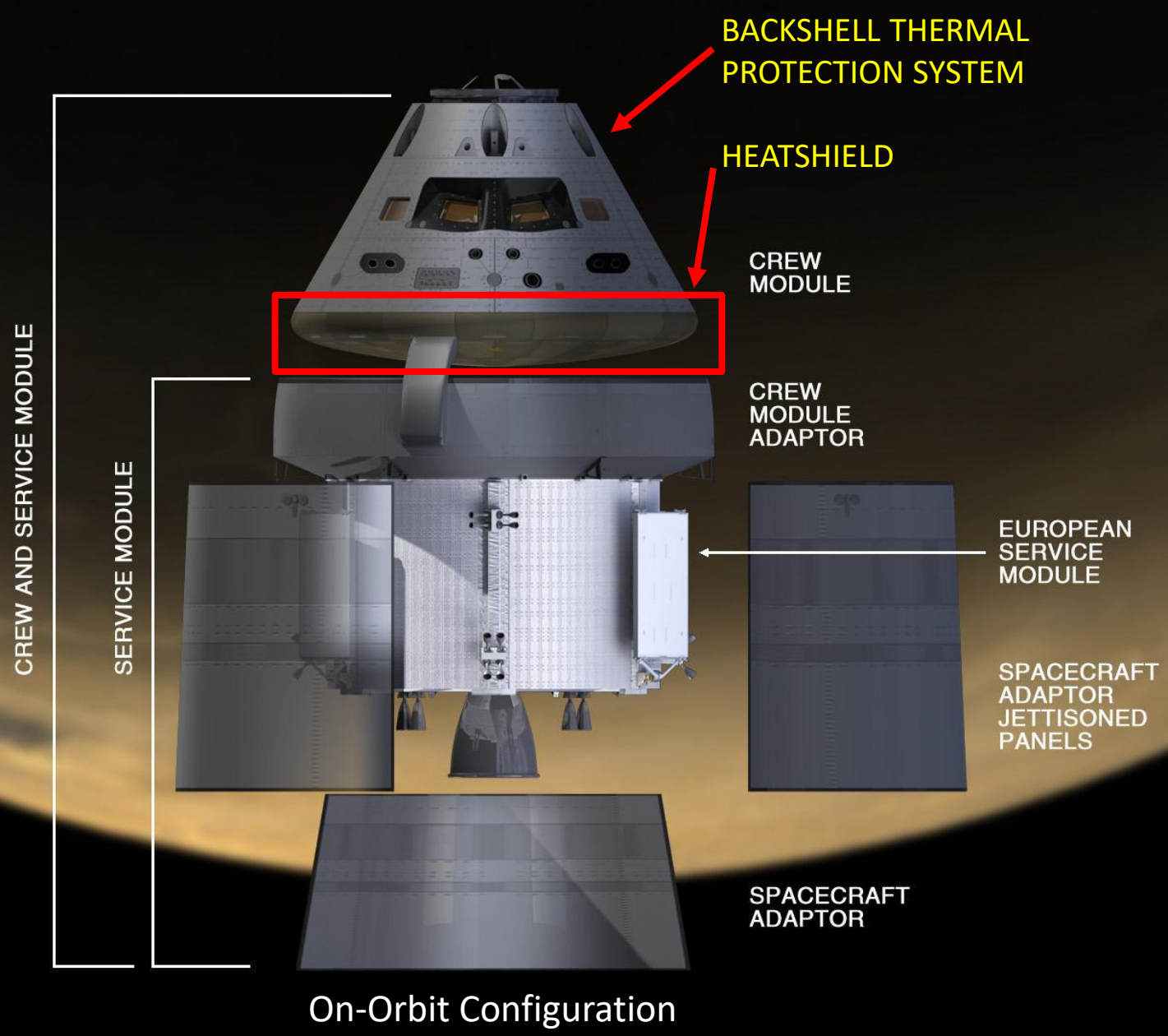
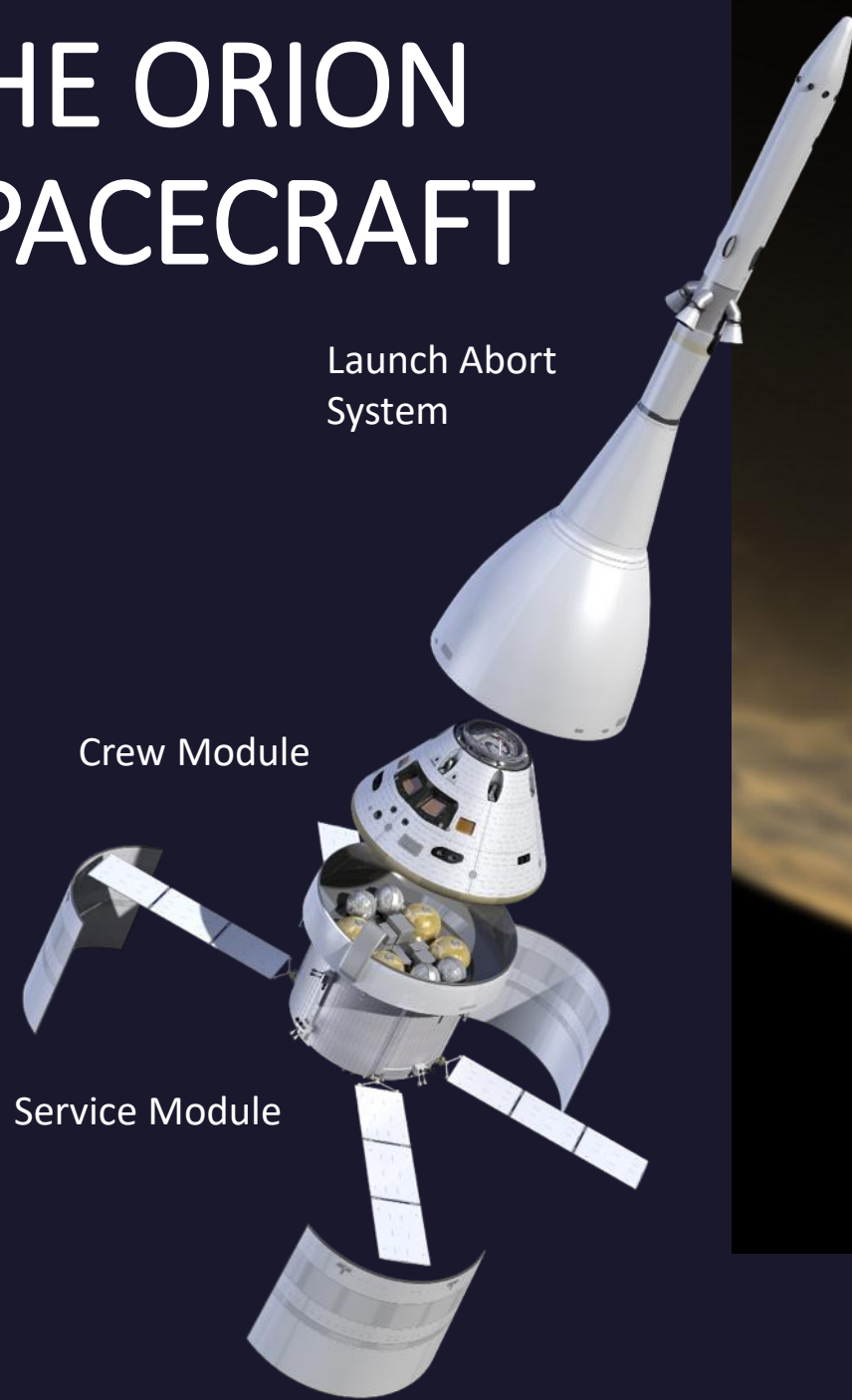


CREW AND SERVICE MODULE

SERVICE MODULE



# THE ORION SPACECRAFT





# Artemis I Payloads

*Science and technology investigations and demonstrations paving the way for future, deep space human exploration*



## Moonikin Campos

The Moonikin is a male-bodied manikin previously used in Orion vibration tests. Campos will occupy the commander's seat inside and wear an Orion Crew Survival System suit



## Radiation Sensors

There will be three types of sensors, including the ESA Active Dosimeters, Hybrid Electronic Radiation Assessor, and the Radiation Area Monitor.



## MARE

Radiation shielding Personal Protection Equipment (radiation vest) for astronauts.



## Crew Interface

### Technology Payload (CITP)

Creates an interactive experience between Orion and the public during the mission



## Bio-Experiment-1

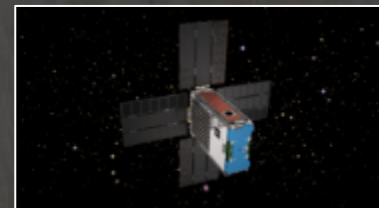
Battery-powered life sciences payload for biology research beyond low-Earth orbit (LEO)



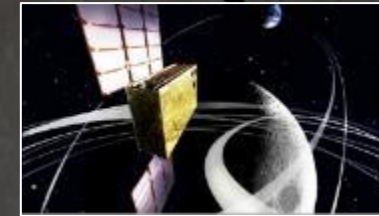
## LunaH-Map



## LunIR



## BioSentinel



## EQUULEUS



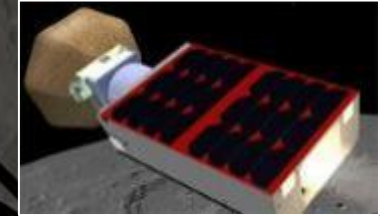
## Near-Earth Asteroid Scout (NEA Scout)



## Team Miles



## ArgoMoon



## OMOTENASHI



## Lunar IceCube



## CuSP

# ARC Technical Support Areas

Crew Service Module (CSM) : TS, AA



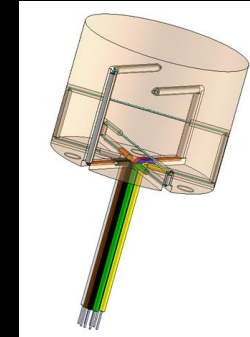
Heatshield testing, system analysis, recovery and post flight support



Backshell testing, analysis recovery and post flight support

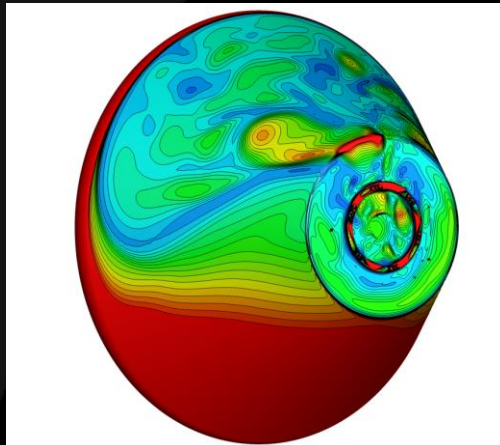


Arcjet testing

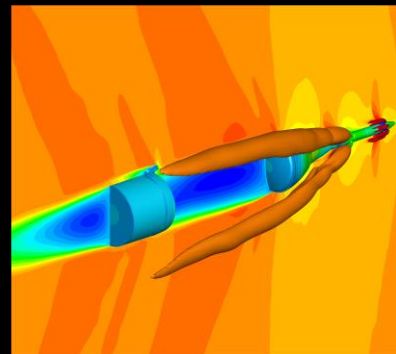


TPS Development Flight Instrumentation (DFI)

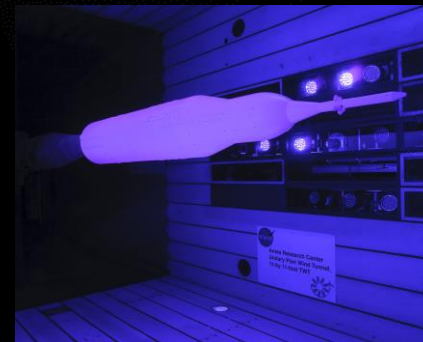
Vehicle



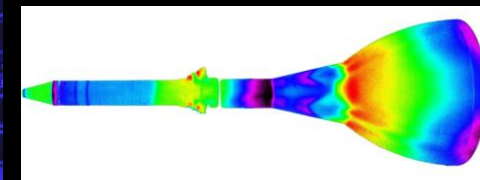
Aerothermal environment and Aerothermal database generation



Vehicle Aerodynamics, wind tunnel test support and aero database



wind tunnel testing

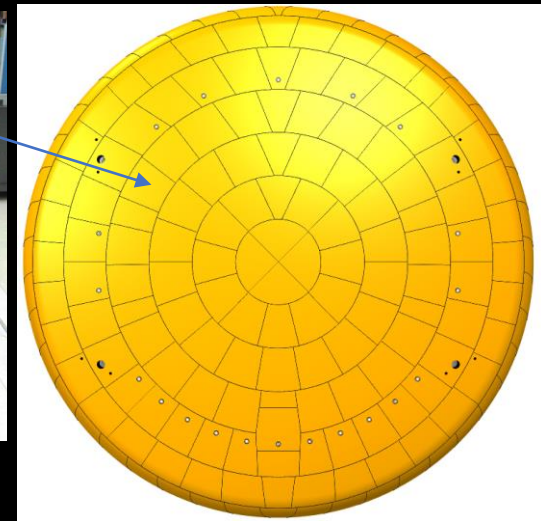
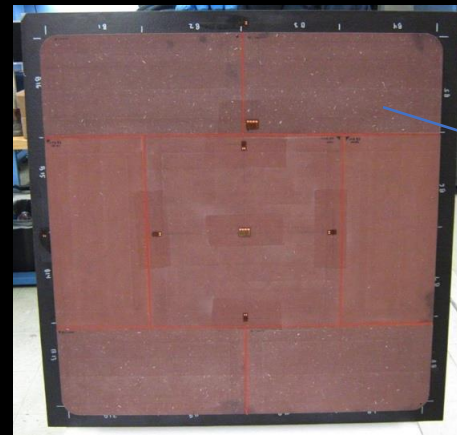


Launch abort environments, acoustics and vibrations



# Orion TPS - Heat Shield

- The Apollo Honeycomb/Gunned (HC/G) system was flown on EFT-1 in 2014
  - Avcoat 5026-39 HC/G
  - Composite/Ti carrier structure
- For Artemis missions, the Orion baseline is Molded Avcoat blocks
  - Avcoat 5026-39 M
    - No honeycomb
    - Bonded to the carrier with EA9394 epoxy
  - RTV-560 between blocks
  - Composite/Ti carrier structure
    - Reduced mass from EFT-1



# Heatshield Fun Facts

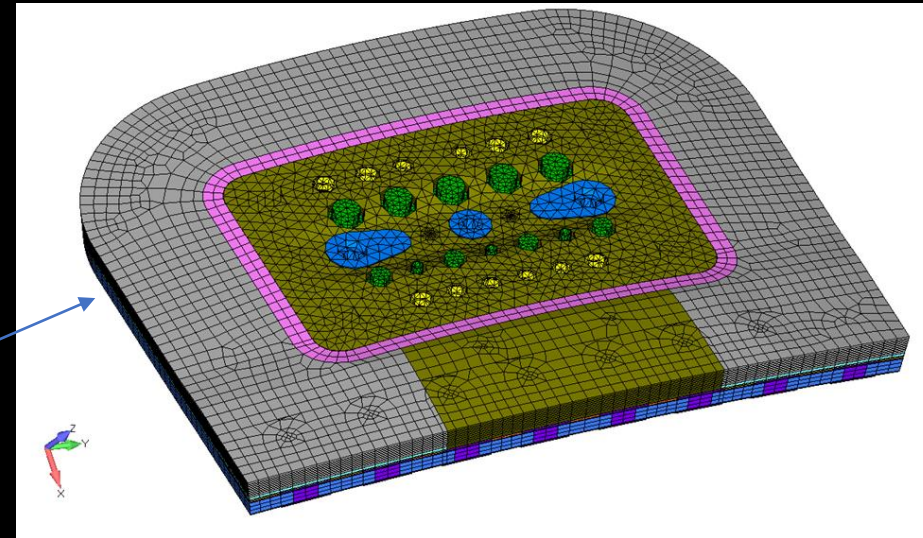
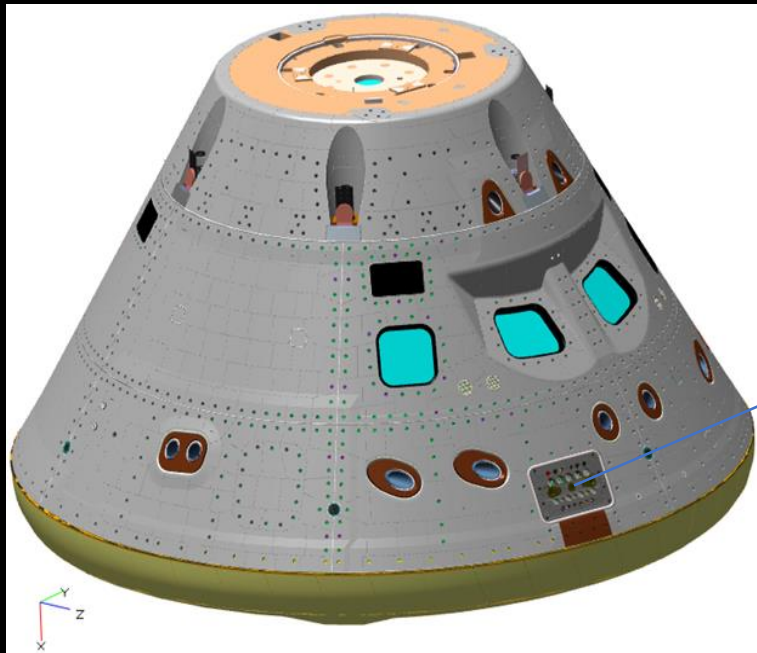
- » During return to Earth from a mission to the Moon, Orion and its heat shield must protect the vehicle and crew from external temperatures up to around 5,000°F.
  - » This is hotter than the melting point for titanium, which is about 3,000°F.
  - » It's also about half the surface temperature of the Sun, which is about 10,000°F.
- » While the outside temperatures during entry into Earth's atmosphere will reach 5,000°F, inside the spacecraft it will be in the mid-70s – hotter than molten lava on the outside and cool as a cucumber on the inside.
- » The heat shield on the bottom of the crew module is 16.5 feet wide. It is the largest ablative heat shield in the world. Orion's thermal protection system is one of the most important parts of the spacecraft and is responsible for protecting the astronauts during their return.





# Orion TPS – Systems Analysis

ARC System analysis group provides insight/oversight for LM analysis, thermal analysis, thermal response analysis, arc-jet and other test data interpretation, guidance in arcjet test design and planning etc.

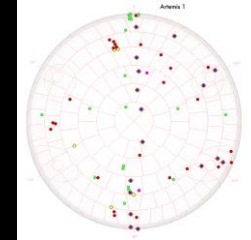


Thermal Analysis and verification of umbilical panel

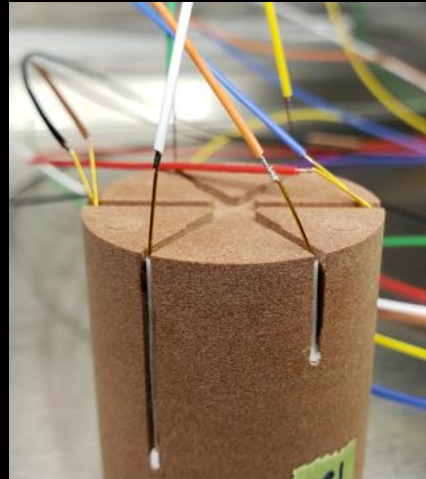
In addition, ARC TPS team is actively supporting pre and post Artemis 1 flight planning, recovery and post flight TPS analysis.

# Orion TPS DFI (Developmental Flight Instrumentation)

- Objective - deliver Artemis 1, 2, 3 + instrumentation hardware (heatshield and backshell) for measuring TPS performance, aerothermal environments, vehicle wind-relative orientation, and atmospheric density during the atmospheric entry of the Crew Module (CM).
- Both heatshield as well as the backshell have numerous embedded sensors that include – Thermal plugs, Flush Air Data System (FADS), shoulder pressure transducers, Radiometer, Spectrometer and Optical recession sensors



Artemis 1 FADS pressure transducer



Artemis 1& 2 Thermal Plugs with embedded Thermocouples

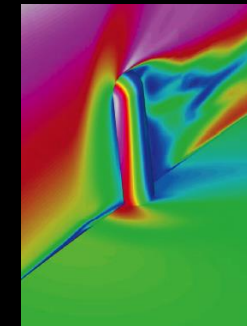
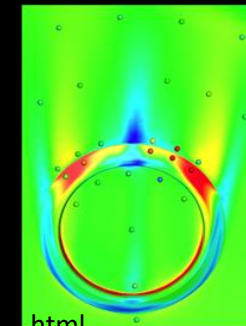
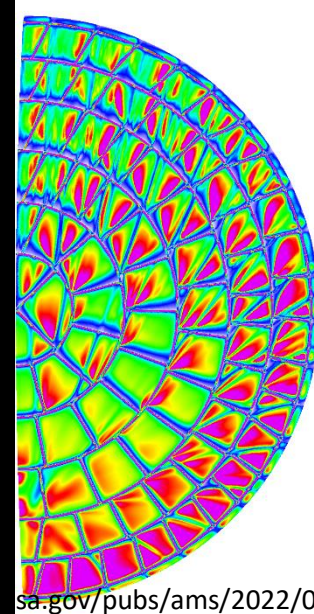
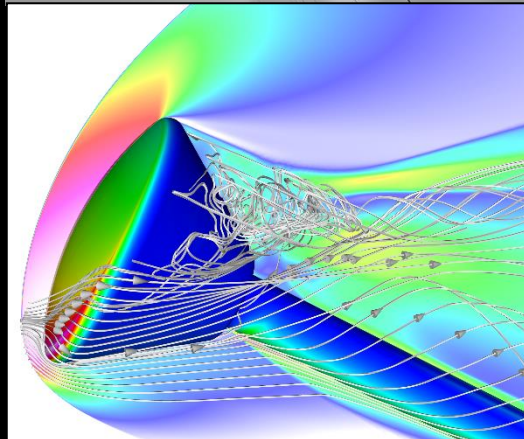
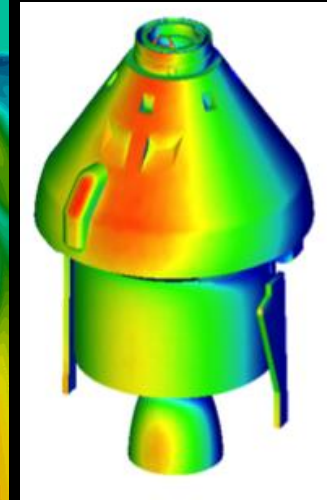
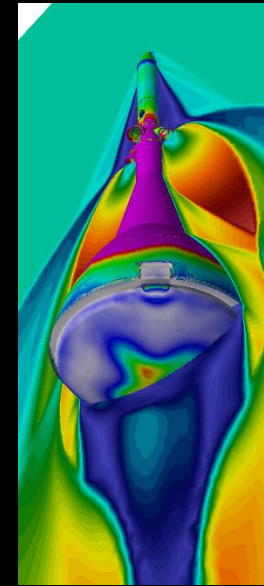
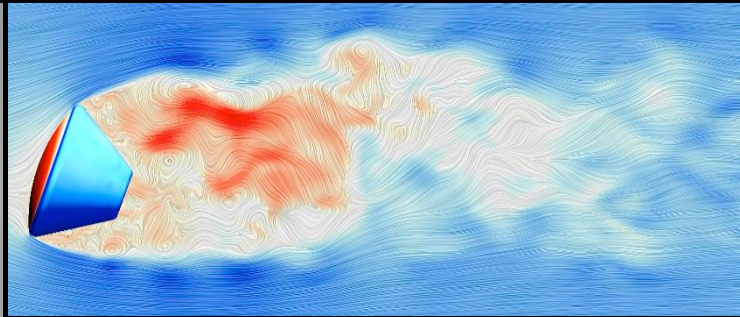
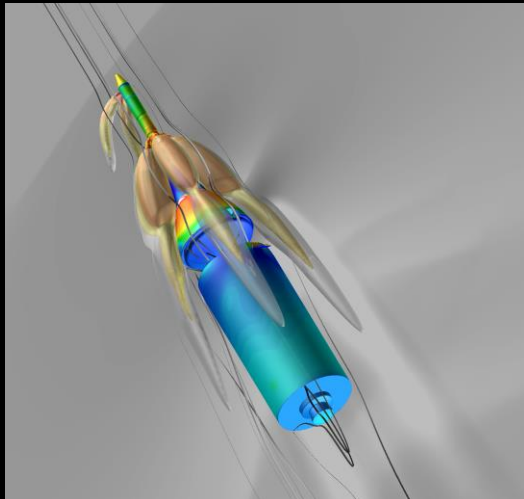


Artemis-1 Radiometer sub-assembly



# Orion Aerosciences

- CFD is used to develop environments for Aerodynamics and Aerothermodynamics for all phases of flight
- CFD tools are validated utilizing ground and flight test data before applying it in design analyses
- Key challenges for CFD in Orion Aerosciences
  - Aero: Complex geometries, turbulence, wake flows, plume flows, fluid-structure interaction (parachutes)
  - Aerothermal: Complex geometries, turbulence, wake flows, plume flows, gas-surface chemical interaction, radiation



reference : <https://www.nasa.gov/pubs/ams/2022/04>

<https://www.nasa.gov/pubs/ams/2022/04>

html

# Launch Abort System



## Ensuring Astronaut Safety

NASA is developing technologies that will enable humans to explore new destinations in the solar system. America will use the Orion spacecraft, launched atop the Space Launch System rocket, to send a new generation of astronauts beyond low-Earth orbit to places like an asteroid and eventually Mars. In order to keep astronauts safe in such difficult, yet exciting missions, NASA and Lockheed Martin collaborated to design and build the Launch Abort System.



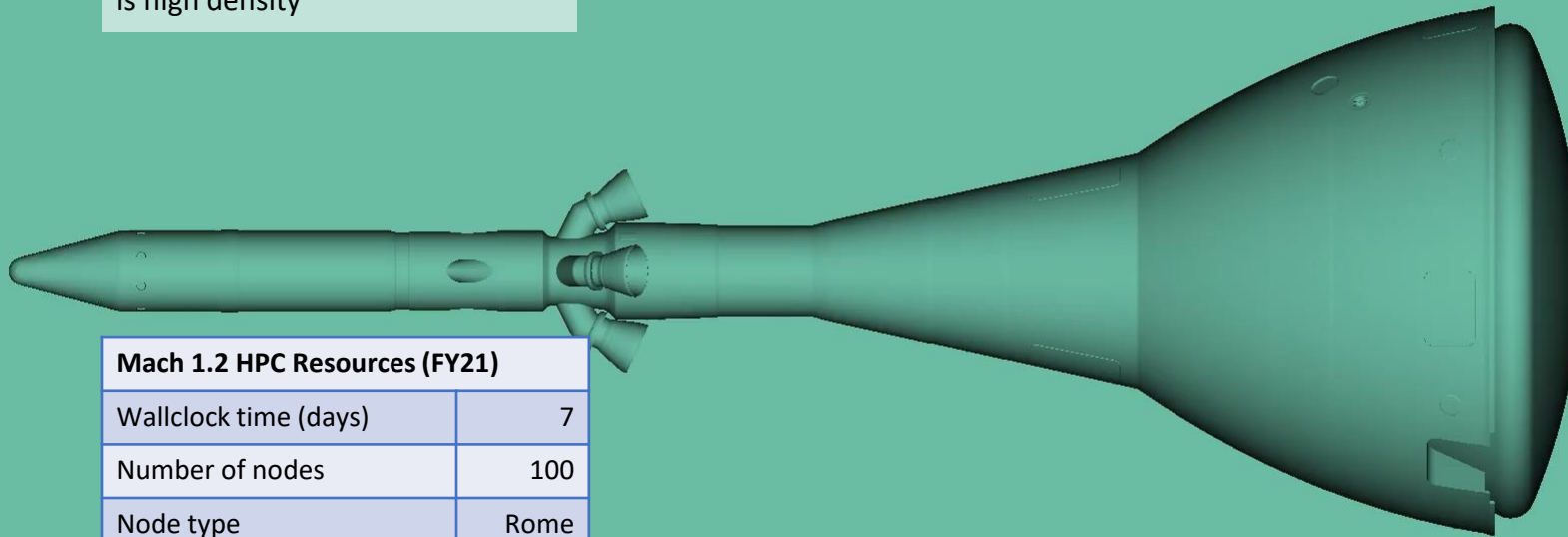
# Ascent Abort Flight Test (AA-2)



- Date: July 2, 2019
- Vehicle: Launch abort vehicle atop Northrop Grumman provided booster
- Trajectory: Abort occurs at Mach 1.17 and accelerates to Mach 1.6

# AA-2 Mach 1.2 Simulation

Video from AA-2 Mach 1.615 simulation: logarithm of density on the cut plane and vehicle surface, where red is low and blue is high density



Mach 1.2 HPC Resources (FY21)	
Wallclock time (days)	7
Number of nodes	100
Node type	Rome
Total number of cores	12,800
Time simulated (seconds)	0.58
Volume data (TB)	100



# ARTEMIS-1 Successes!



SUCCESSFUL LAUNCH OF MOST POWERFUL ROCKET IN THE WORLD



ORION HEADED TO THE MOON

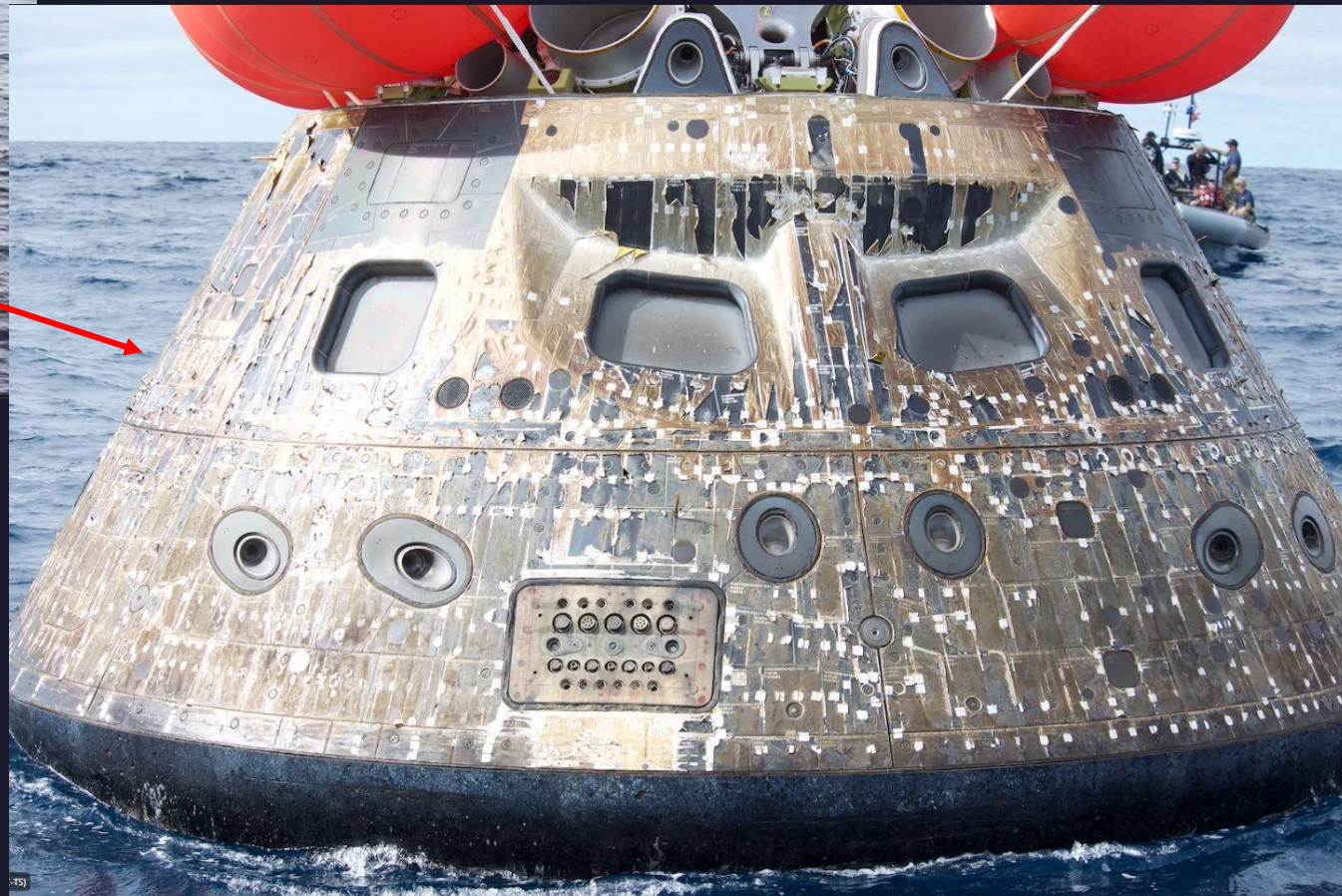


ORION IN DISTANT RETROGRADE ORBIT  
CAPTURES MOON TRANSIT IN FRONT OF EARTH



# ARTEMIS-1 Successes!

SUCCESSFUL RECOVERY IN THE PACIFIC OCEAN





# ARTEMIS

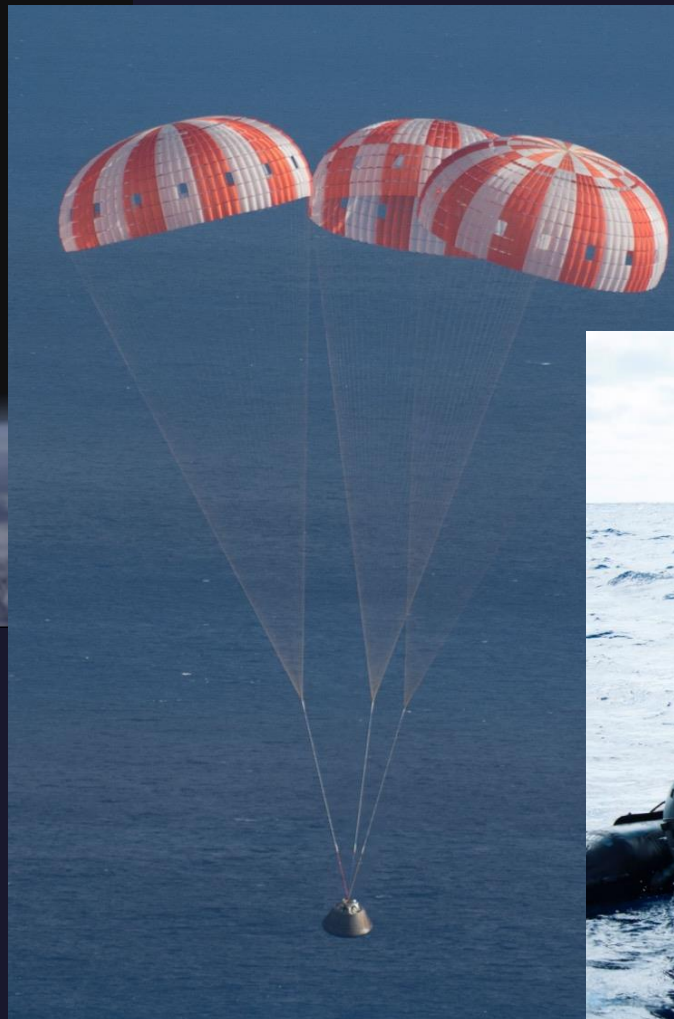


## QUESTIONS?

# A SAFE RETURN



Returning to Earth at  
25,000 MPH







# A SAFE RETURN

## Survive Extreme Heating!



Returning to Earth at  
25,000 MPH

The capsule must survive external **temperatures as high as 5,000 °F!** That's half the surface temperature of the Sun!!!!

Our heat shield technology helps keep the inside of the capsule (where the humans will live!) in the mid-70 °F

This is the largest ablative heatshield in the world at **16.5 ft in diameter!**



# A SAFE RETURN



Returning to Earth at  
25,000 MPH



Safe Recovery of the Capsule





# A SAFE RETURN

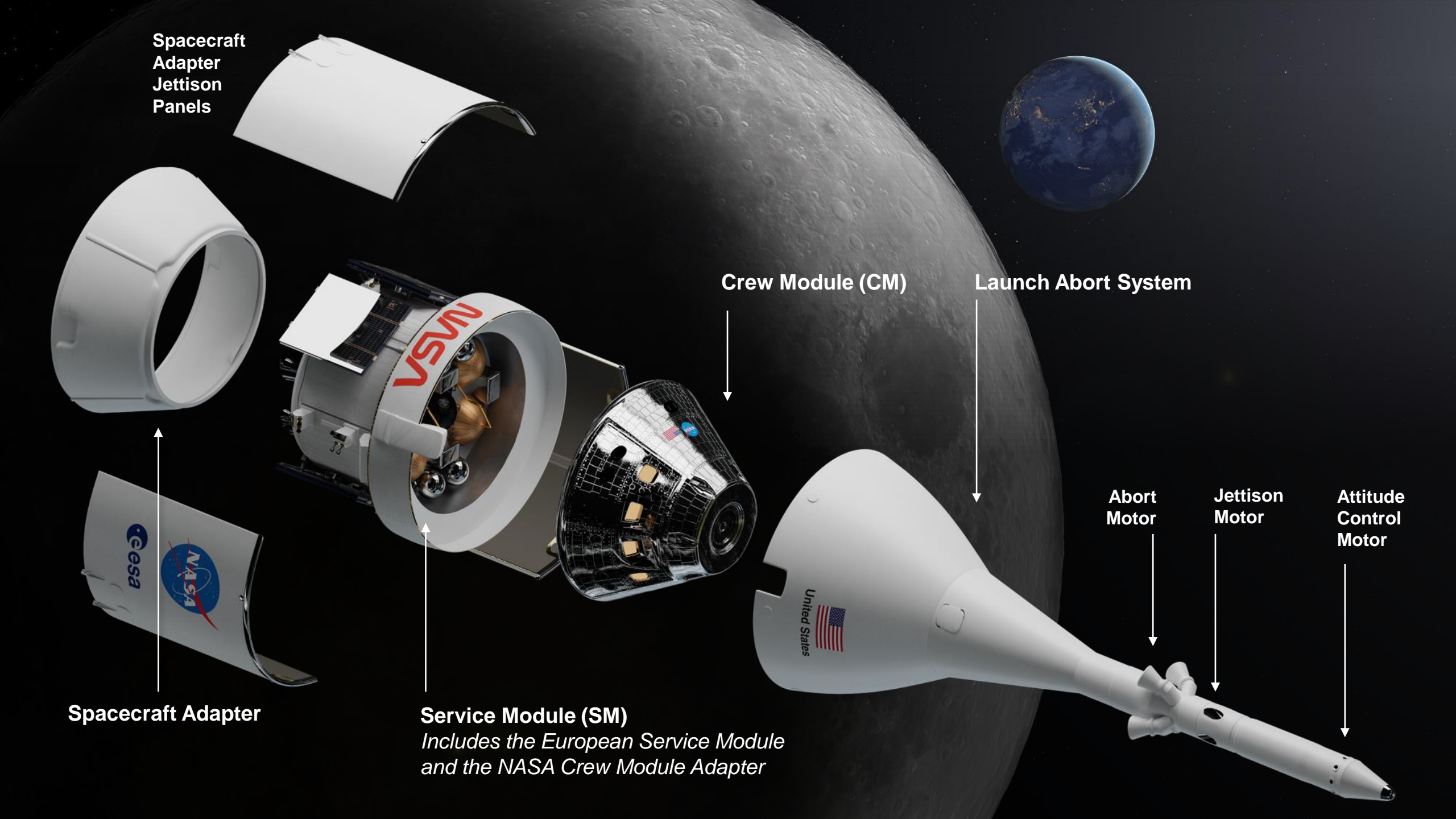


Returning to Earth at  
25,000 MPH

## Put on the Brakes!



Orion is equipped with 11 parachutes that are deployed to **slow the vehicle from 325 mph to 20 mph** for a soft landing in the ocean.



Spacecraft  
Adapter  
Jettison  
Panels

Crew Module (CM)

Launch Abort System

Abort  
Motor

Jettison  
Motor

Attitude  
Control  
Motor

Spacecraft Adapter

Service Module (SM)  
*Includes the European Service Module  
and the NASA Crew Module Adapter*